Synopsis of the Ph.D.thesis entitled

Experimental analysis, Investigation and development of Disc Brake Pad

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By

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Introduction: A disc brake pad is one of the important components in an automobile, as it ensuring both human safety and vehicle performance. The primary function of the brake system is to stop the vehicle within the minimum possible distance while ensuring the driver to maintain proper control on the Vehicle. Braking occurred due to the friction between the brake pad and disc surface. Brake pads are generally manufactured from composite materials—engineered or naturally occurring combinations of two or more constituents with significantly different physical or chemical properties. These constituents remain separate and distinct within the final structure, offering desirable mechanical and thermal characteristics.

Historically, asbestos was widely used as a brake lining material due to its advantageous properties. Asbestos exhibits thermal stability approximately up to 500**°C**, above which it forms silicates. The silicates produced are harder, more abrasive, and help regenerate the friction surface during braking. Additional benefits of asbestos include:

- Good thermal insulation
- Excellent wear resistance
- High strength with flexibility
- Ease of processing
- Availability at a reasonable cost

The fibrous structure of asbestos remains stable up to nearly 1400°C, making it highly suitable for friction applications.

However, extensive medical research has shown that asbestos fibre pose severe health hazards. Prolonged exposure can damage the respiratory system and kidneys and may lead to life-threatening diseases, including cancer. Due to these risks, the Environmental Protection Agency (EPA) and other global regulatory bodies have banned or restricted for the use of asbestos-based materials.

As a result, researchers and manufacturers are now focusing on developing asbestos-free composite brake pads using alternative materials that can deliver comparable or superior friction, wear, and thermal performance. The effectiveness of these new materials is evaluated using established standards such as:

- SAE J661 – Friction Test Procedure
- IS 2742 (Part 2): 1999 – Automotive Brake Lining Specifications

The objective of ongoing research is to identify environment safe, cost-effective, and high-performance material compositions that can successfully replace asbestos in disc brake pad applications.

Objectives.

The present work focuses on the development and evaluation of an asbestos-free disc brake pad material. The specific objectives of the study are as follow.

1. To develop a new disc brake pad that provides stable coefficient of friction under various operating condition.
2. Minimum wear rate of Disc Brake Pad (In terms of weight loss and thickness loss during braking cycle).
3. To Determine Maximum Temperature that can be withstand by the non asbestos material without functional failure.

Scope of work:

In recent years the global market has increased demand of Automobile, resulting in an increased demand for eco friendly and safer, durable braking systems, With the restrictions and bans on asbestos-based friction materials due to critical health issues. The need for non-asbestos brake pads has become critical. Below table shows how the demand of Car increases globally and in Indian market from 2019 to 2025.

Table No: 1 Globally Sales of Cars From year 2019 to 2025

Sr.No.	Years	Cars Sale in (Million Units)	Remark if any
1	2019	64	(Covid)
2	2020	55	Covid lockdown Factory Shut down
3	2021	57	Partial Recover
4	2022	61	Continue recovery
5	2023	65	Growth
6	2024	67	Demand Increases
7	2025	70	Demand Increases

Table No:2 Indian Market Sales of Cars From year 2019 to 2025.

Sr.No.	Years	Cars Sale in (Units)	Remark if any
1	2019	33,77000	(Covid)
2	2020	27,73000	Covid lockdown Factory Shut down
3	2021	27,11000	Partial Recover
4	2022	30,69,499	Continue recovery
5	2023	37,92000	Growth
6	2024	4218000	Demand Increases
7	2025	4301848	Demand Increases

Source: Society of Indian Automobile Manufacturers.

1. The increasing demand of Cars direct impact on the environment, Higher the car usage contribute in air pollution, which leads worsen air quality index and causes severe health issues, particularly affecting the human respiratory system. Therefore, it is essential to select brake pad composition that minimizes environmental pollution and exhibit lower wear rates.
2. This Study focuses on the development of non-asbestos disc brake pad materials and the evaluation of their performance. The proposed materials will tested in accordance with standard procedures such as SAE J661**,** TS 2642 and other relevant standards specified in the thesis report. Furthermore, The results obtained from the experimental testing will be validated through wear estimation using mathematical models, supported by experimental data and actual field trials on a vehicle,

Work done:

In this research, a detailed analysis and investigation of different disc brake pad material characteristics were carried out. The study involved an extensive literature survey, consultation with industrial experts, and testing of various brake pad materials. Based on these evaluations, the most suitable non-asbestos brake pad composition was selected. The selected material compositions were then tested using standard procedures specified in ISO and SAE standards, including SAE J661. The performance results were further validated through, Actual field trials on a car, (measuring brake pad wear in terms of thickness and weight loss)and wear estimation using mathematical models with experimental data to compare and correlate with experimental results.

A non-asbestos brake material composition generally contains four main components.

1. Fibre Reinforcement.2.Resin Binders 3.Friction modifiers 4.Fillers & Abrasive

, Detailed are explained below.

1.Fibre Reinforcement: The purpose of these material is to provide heat resistance and stable coefficient of friction,commonly used fibre reinforcement material are Kevlar, Ceramic fibre, Basalt, Cellulose,glass fibre,polyester.in the brake pad material compositions, fibre reinforcement are generally used up to 50%.

2.Resin binders: The purpose of these material is to bind all the material in to solid form, commonly used Resin binders are Rubber-modified phenolic,Epoxy-modified phenolic , Silicone-modified phenolic,Nitrile rubber (NBR) Resin binders are generally used up 10%. to 30%.

3.Friction Modifiers: The purpose of these material is to adjust friction level, minimize the noise level and to reduce wear,commonly used Friction Modifiers are Graphite, Carbon black, Cashew friction dust, Metal sulphides, Metal oxides, Copper, Steel wool fibers. Friction Modifiers are generally used up to 25%.

4. Fillers and Abrasive: The purpose of these material is to give constant hardness, wear and to control Dust to avoid air pollution commonly used Fillers and Abrasive are Barite, Calcium carbonate, Vermiculite, Mica, Rubber dust, Metallic fillers . . Fillers and Abrasive are generally used up to 10% to 30%.

The proper material and percentage of each material significantly influences on mechanical, chemical and physical properties of developed brake pad material .Therefore optimizing the brake pad material formulation is essential to achieve required performance of Disc Brake pad.

Fig 1 : Analysis and investigation of different disc brake pad materials.

The following formulation were prepared and tested as per SAE J661 And IS standards to evaluate their capability to replace Asbestos material:

Table 3:Materials Composition for Sample-S1

Sr.No	Material	% by Weight
1	Ceramic Fibre	9
2	Steel Wool	30
3	Aluminum oxide	8
4	Calcium Carbonate	6
5	Resin PR 201	10
6	Friction Dust	4
7	Lapinus RB 250	6
8	Natural barytes	15
9	Syn.Graphite	8
10	Copper Powder	4

Table 4: Material Composition for Sample-S2

Sr.No	Material	% by Weight
1	Ceramic Fibre	7
2	Steel Wool	24
3	Aluminum oxide	5
4	Kevlar	8
5	Resin	9
6	Friction Dust	5
7	Antimony trioxide	4
8	Natural Barytes	15
9	Lapinus RB 250	5
9	Syn.Graphite	8
10	Copper Powder	5
11	Whiting powder	5

Different Disc Brake Pad Testing conducted on selected two disc Brake pad material.

1. Coefficient of Friction Test : The test Conducted using Link Chase Frictional material testing machine to determine Normal Friction and Hot Friction characterstics.
2. Thermo gravimetric Analysis (TGA): TGA Used to measure the maximum temperature resistance and thermal stability of the material
3. Specific Gravity Test: To determine density and uniformity of material.

4. Hardness Test: It is used to evaluate Surface hardness and wear resistance of the brake pad.

5. Acetone Extraction Test: It is used to to calculate percentage of organic binders present in the material.

6. Loss on Ignition@850℃:It is used to calculate the amount of combustible and volatile matter in the brake pad.

7. Heat Swell@200℃: It is used to measure dimensional changes due to **thermal expansion**.

8. Water Swell @ Room Temperature. Used to access material moisture absorption and stability.

9. Cold Shear Strength. It is used to measure bonding strength between the lining material and backing plate.

10. Adhesion. It is used to evaluate the adhesion properties of friction material under load.

Contributions made to the existing knowledge in the subject: This research provides a systematic approach to the development of non-asbestos disc brake pad composites, their testing through advanced laboratory equipments and validation through actual field trials on a car for approximately 16,000–20,000 km. additionally, a wear estimation using mathematical models supported by experimental data is performed.

Addressing Knowledge Gaps: Necessity to Replace Asbestos Material due to the global ban and health issue with asbestos, finding the environmental friendly and technically efficient material.

- Understanding how factors such as temperature, pressure, coefficient of friction, hardness, and specific gravity influence braking performance.
- Finding out best **substitute for asbestos material** using standard testing methods.
- Limited availability of long distance field trial data for non-asbestos brake pads.

Critical Analysis: The thesis critically evaluates previous research and focuses on below given points:

- Comparative study of different non-asbestos material compositions.
- Various standard testing methods for performance evaluation.
- Field trials to measure real-world wear and braking behaviour.

This leads to enhanced understanding of friction material behaviour and optimization.

Knowledge Implication: The research work integrates comprehensive information from the

- Disciplines of Mechanical Engineering particularly the domain from engineering Metallurgy, material science and brake friction composites.
- Standard Testing Procedure and different Material characteristics.
- vehicle field Trials
- Mathematical Wear modeling

Policy Implication: The findings may support regulatory and industrial decision-makers on:

- Encouraging for environment-friendly brake pad materials
- Comparing machine test results, field performance, and mathematical validation
- Reducing air-pollution

IPR Development:

The research outcomes include two conference presentations (with published proceedings) and five research papers. Two papers are published in Scopus-indexed journals, two are currently under Scopus review, and one is under review in web of science.

Originality: This study is distinguished by different Machine test results and a real-time field trial of more than 16,000 km conducted on a car, continuously monitoring the performance, wear behaviour, thickness reduction, and weight loss of the disc brake pad, ensuring strong originality and practical applicability.

Fig 2: Field trial Tested and untested sample.

Fig 3 : Field Trial sample Mounting

Data collection and analysis: Use of frictional testing machine to test friction materials as per SAE-J661 and BIS-2742 of 1999 part-II

Fig 4: Friction Material Testing Machine.

Fig 5 : Friction Material Testing Machine.

Procedure for Sample Making.

For testing friction materials as per SAE J661, rectangular flat specimens were prepared with dimensions of 25.4 mm × 25.4 mm and a thickness of approximately 7 mm. The flat sample were then shaped to drum by sanding them against abrasive paper mounted on separate drum because of that the sample one side is flat while other is curved (The curved surface is prepared to match the drum profile during testing, ensuring proper contact between the specimen and the test drum).

Principal of Frictional Testing Machine: The prepared sample is mounted in the arm or clamp of the friction testing machine. The cast-iron drum, which has a nominal diameter of 280 mm and a Brinell hardness of 210 HB, is then rotated at the desired speed. Once the target speed is reached, braking is applied using a hydraulic cylinder, causing the drum and the liner (or sample) to rub against each other. This interaction generates friction, which eventually brings the drum to stop and allows the coefficient of friction to be measured. An electric heater and air blower are used to control and maintain the temperature of the testing drum during the process.

Table 5: Specification of the machine used

Sr.No.	Parameters	Unit	Min	Max	Remark
1	Drum Speed	Rpm	0	1200	
2	Test Load (Load Cell)	N	0	2000	
3	Drum Temperature	Degree F	0	750	Controlled with J661 requirement
4	Drum Inner Dia	MM	277	289	

Table 6 Test Schedule as Per SAE J661

Sr.No	Block	Temperature(^{0}F)		Number of applications
		Min.	Max.	
1	Baseline-I	93	93	20
2	Fade-I	200	550	1
3	Recovery-I	500	210	1
4	Wear	93	500	100
5	Fade-II	210	650	1
6	Recovery-II	610	225	1
7	Baseline-II	93	93	20

Important parameters of link Chase Machine:

1. Measuring Drum Rotation Speed.
2. Load Cell to give frictional force

3 Measuring drum temperature.

3 Heater used for heating the drum.

4 Heating rate

5 Blowers for cooling the drum

6 Measuring frictional force (1.3 kg max).

Accuracy of measurement

1. Temperature ± 2% full scale accuracy
2. Friction force ± 2% full scale accuracy
3. Drum speed ± 2% full scale accuracy

Drum heating

Speed – 411 rpm

Cool 149 to 93 °c with cooling air and then cool to 82°c with cooling air off

82 to 221°c ±14 °c in 10 minutes

Drum cooling

345 to 93 °c ±14°c in 10 minutes

Checking the Coefficient of friction as per SAE – J-661

Table 7: Checking the Coefficient of friction as per SAE – J-661

Sr.No	Name of Test	Unit	Specification
1	Normal Friction	μ	0.300 - 0.541
2	Hot Friction	μ	0.313 - 0.559
3	Weight Loss	%	8.0 Max
4	Thickness loss	%	9.0 Max

Table 8Test Method as per IS 2742 (part 2):1999 Standard:

Sr.No	Name of Test	Unit	Specification
6	Specific Gravity	g/cc	2.16 - 2.52
7	Hardness on the spigot hole	HRS	42 - 104
	Hardness off the spigot hole		37 - 107
8	Acetone Extraction /15 g Sample in 6 hrs.	%	2.4 max
9	L.O.I.@850°C	%	18.20 - 21.40

10	Heat Swell @ 200°C	mm	0.11 max
11	Water Swell @ Room Temperature	mm	0.10 max

Table 9 Test method as per ISO 6312 /SAE J840

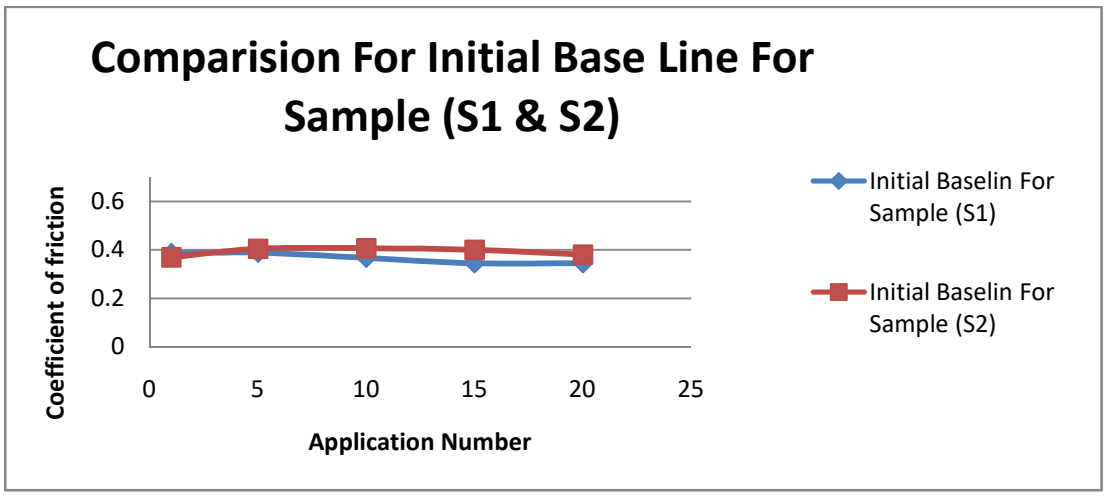
Sr.No	Name of Test	Unit	Specification
12	Cold Shear Strength	Kg/cm2	25.50 Min
13	Adhesion	%	100

Table 10 Test method as per JIS D 4418

Sr.No	Name of Test	Unit	Specification
14	Porosity	%	6 % target

Results and discussion:

Comparison for Initial Base line Test:

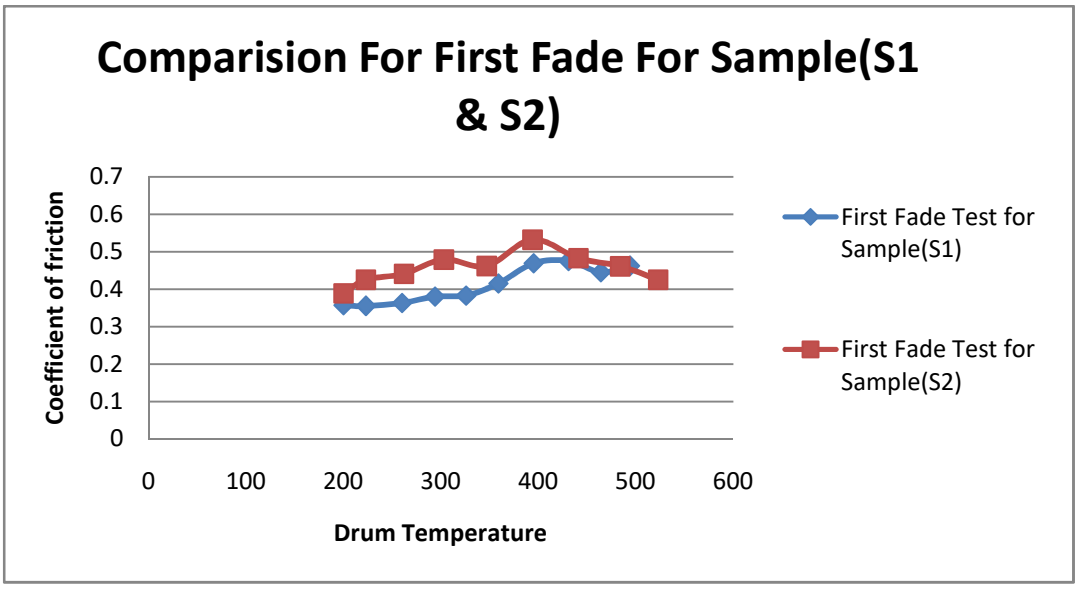


Graph: 1 Comparison for Initial Base line for sample-S1 & S2

The graph between coefficient of friction and number of brake application is plotted to analyze the effect of number of brake application and coefficient of friction. The results

shows that as the number of brake application increases the coefficient of friction for sample S1 decreases and for sample S2 it increase at the Start and then stabilize, The standard deviation of coefficient of friction for S1 is 0.02 and coefficient of variation 5.6% . The standard deviation of coefficient of friction for S2 is 0.01 and coefficient of variation 4.2%. both sample shows stable coefficient of friction during initial baseline test.During this test, the profile of the sample matches the profile of the drum to ensure proper contact.

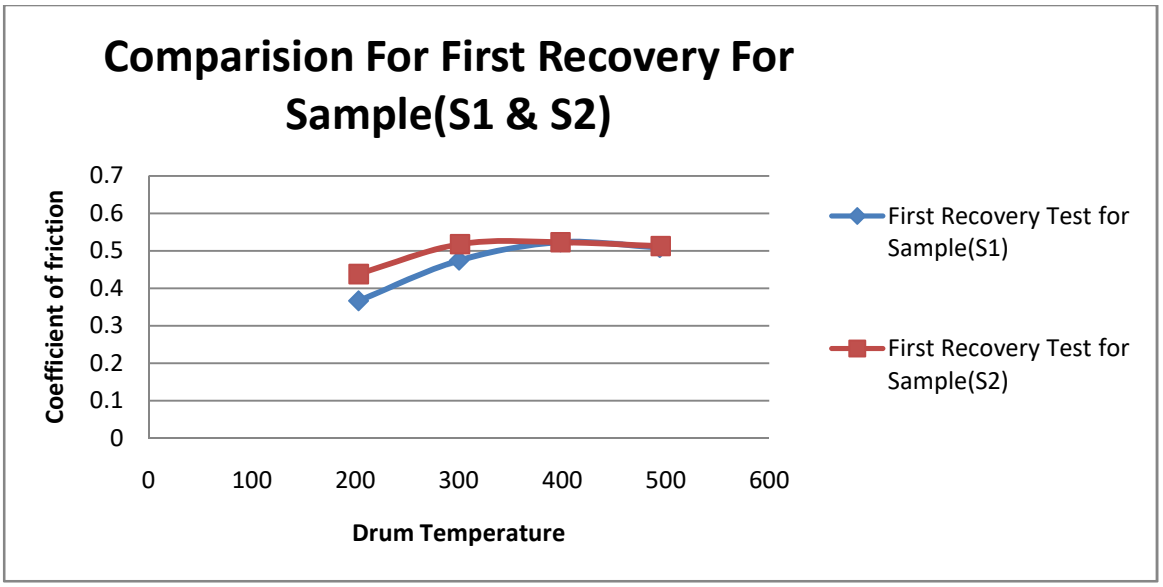
Comparison for First Fade Test:



Graph: 2 Comparison for First fade for sample-S1 & S2

The graph between coefficient of friction and drum temperature for first fade test is plotted to analyze the effect of drum temperature on coefficient of friction. Initially the drum temperature increases as the coefficient of friction increases .However, once it reaches 400^0c, it will start decreasing and them stabilize at nearly 0.380. The standard deviation of coefficient of friction for sample S1 is 0.0419 and coefficient of variation 10% . Which shows that sample S1 has very stable coefficient of friction during the first fade test . For sample S2 initially as the drum temperature increases the coefficient of friction increases, However once it reaches 400^0F ,it will start decreasing and stabilize at nearly 0.40 **.** The standard deviation of coefficient of friction is 0.0389 and coefficient of variation 8.77%. Both sample shows stable coefficient of friction during first fade test .Both sample run the test without function failure they withstand temperature up to 500^{o}F.

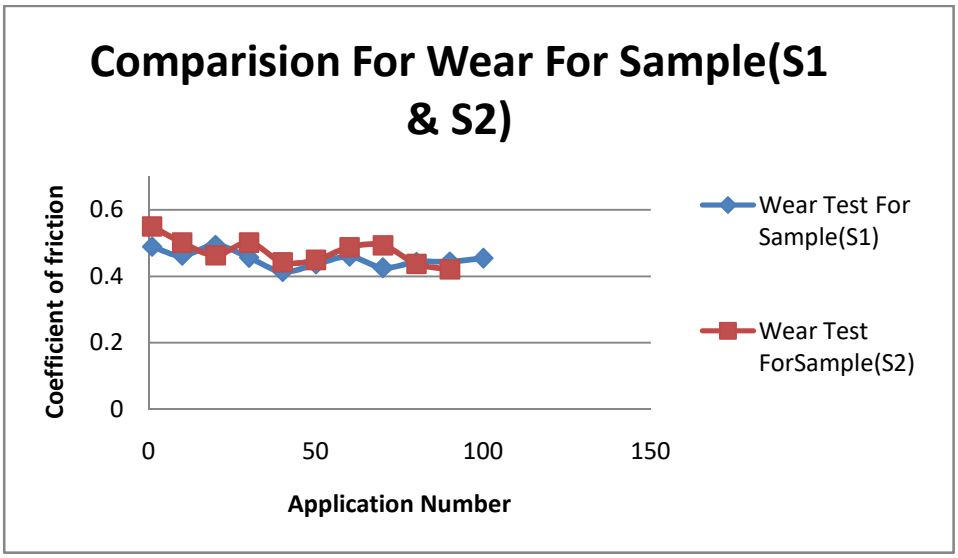
Comparison for first Recovery Test.



Graph: 3 Comparison for First Recovery for sample-S1 & S2

The graph between coefficient of friction and drum temperature for first recovery test is plotted to analyze the effect of drum temperature on coefficient of friction. As the drum temperature decreases, the coefficient of friction decreases. Both samples show good recovery characteristics.

Comparison for Wear Test:



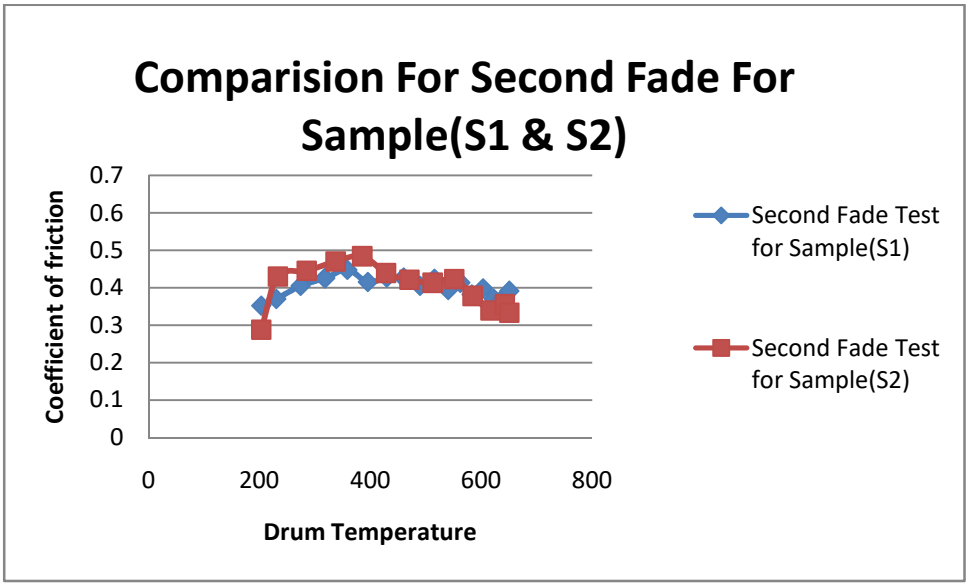
Graph: 4 Comparison for wear for sample-S1 & S2

The graph between coefficient of friction and number of brake application is plotted for wear test. For sample1, it shows stable coefficient of friction with maximum value 0.489 and minimum 0.413. Standard deviation is 0.02 and coefficient of variation 5.40%.

For sample S2, it shows stable coefficient of friction with maximum value 0.55 and minimum 0.42. Standard deviation is 0.03 and coefficient of variation 8.24%.

Although both sample shows stable coefficient of friction, sample S1 exhibits lower wear compare to sample S2.

Comparison for Second Fade Test:



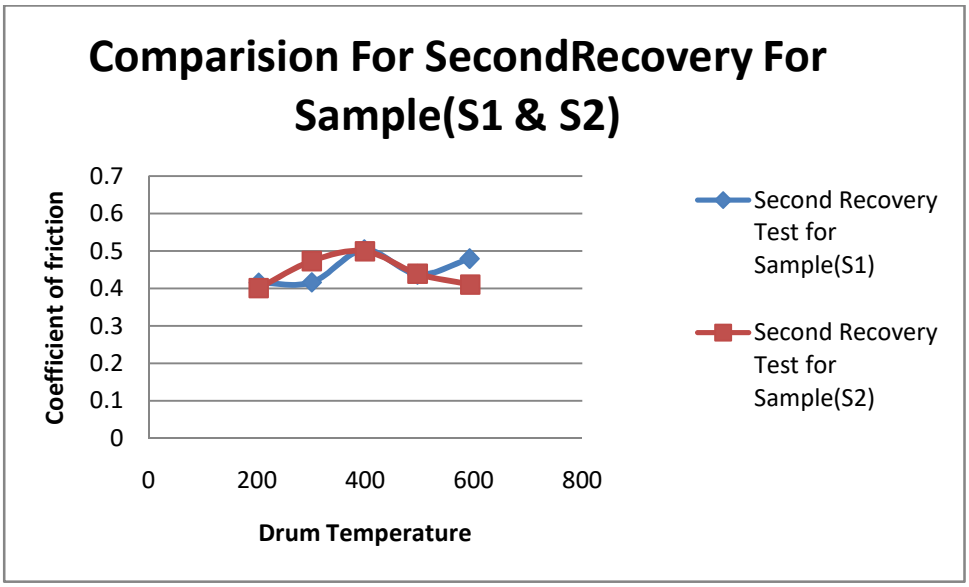
Graph: 5 Comparison for second fade for sample-S1 & S2

The above graph shows the results of comparison of second fade and recovery test for sample S1,S2 where the coefficient of friction is plotted against the brake drum temperature. The maximum coefficient of friction for S1 is 0.448 and minimum coefficient of friction is 0.352. The maximum coefficient of friction for S2 is 0.484 and minimum coefficient of friction for is 0.288.

The standard deviation for sample S1 is 0.39 and coefficient of variance is 7.3%.

The standard deviation for sample S2 is 0.44and coefficient of variance is 16%.From above it is clear that sample S1 is best for maximum temperature.

Comparison for Second Recovery:



Graph 6: Comparison for second recovery for sample-S1 & S2

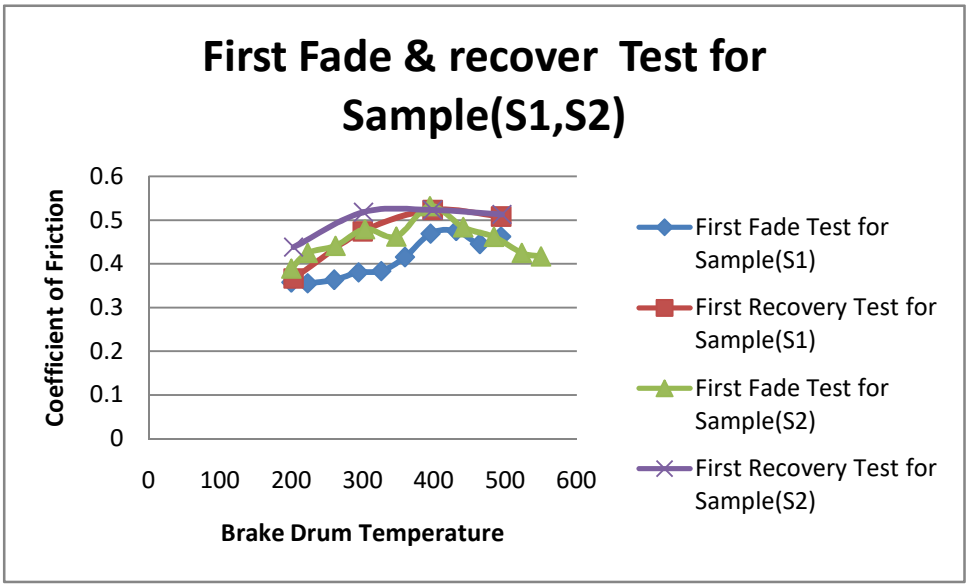
The above graph shows the results of comparison of second recovery test for sample S1,S2 where the coefficient of friction is plotted against the brake drum temperature.

The coefficient of friction for second recovery test of sample S1 is 0.504 and minimum coefficient of friction for Second recovery test is 0.415. The maximum coefficient of friction for sample S2 Second recovery test is 0.499 and minimum coefficient of friction for Second recovery is 0.402.

The standard deviation for Sample S1 is 0.039 and coefficient of variance is 8.7%.

The standard deviation for Sample S1 is 0.04 and coefficient of variance is 9.34%.

Comparison of First Fade & Recovery of Sample S1 & S2.

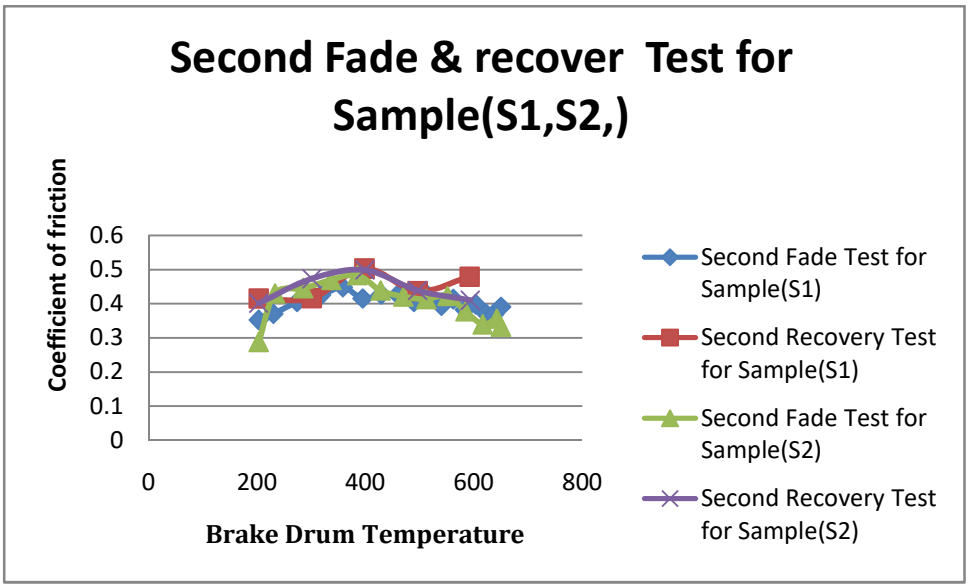


Graph 7: Comparison for first fade and recovery for sample-S1 & S2

The above graph shows the results of comparison of first fade and recovery test for sample S1,S2 where the coefficient of friction is plotted against the brake drum temperature.

From above it is clear that sample S1 is best because it have good Fade and Recovery Characteristics as compare to sample S2..

Comparisons of Second Fade & Recovery of Sample S1 & S2.

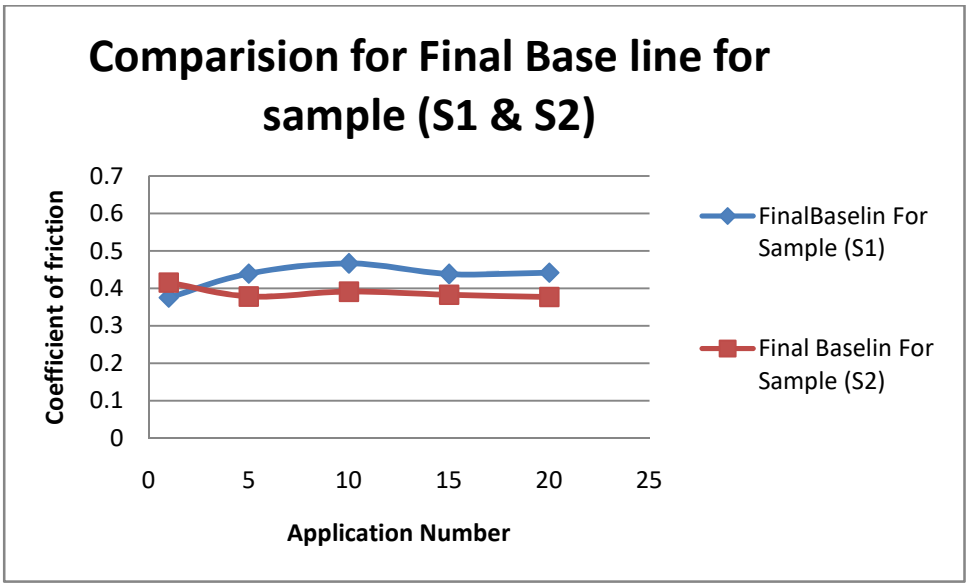


Graph 8: **Comparison for second fade and recovery for sample-S1 & S2**

The above graph shows the results of comparison of first fade and recovery test for sample S1,S2 where the coefficient of friction is plotted against the brake drum temperature.

From above it is clear that sample S1 is best because it have good Fade and Recovery Characteristics as compare to sample S2..

Comparisons for Final Base line for sample (S1 & S2):



Graph 9: Comparison for Final baseline for sample-S1 & S2

The above graph shows the results of comparison of final baseline test for sample S1,S2 where the coefficient of friction is plotted against the brake drum temperature.

Both the Sample Shows Stable coefficient of friction but sample S1 is more stable than S2.

Table 11: Test Results as per SAE – J-661

Sr. No	Name of Test	Unit	Specification	Sample(S1)	Sample(S2)
1	Normal Friction	μ	0.300 - 0.541	0.423	0.390
2	Hot Friction	μ	0.313 - 0.559	0.435	0.443
3	Weight Loss	%	8.0 Max	7.9	8.0
4	Thickness loss	%	9.0 Max	8.0	8.1

Table 12 Test Results as per IS 2742 (part 2):1999 Standard:

Sr. No	Name of Test	Unit	Specification	Sample(S1)	Sample(S2)
5	Specific Gravity	g/cc	2.35 - 2.52	2.48	2.37
6	Hardness on the spigot hole	HRS	42 - 104	76.7	80.2
	Hardness off the spigot hole		37 - 107	77.7	66.3
7	Acetone Extraction /15 g Sample in 6 hrs.	%	2.4 max	0.58	0.69
8	L.O.I.@850℃	%	18.20 - 21.40	18.4	19.4
9	Heat Swell @ 200℃	mm	0.11 max	0.08	0.1
10	Water Swell @ Room Temperature	mm	0.10 max	0.07	0.09

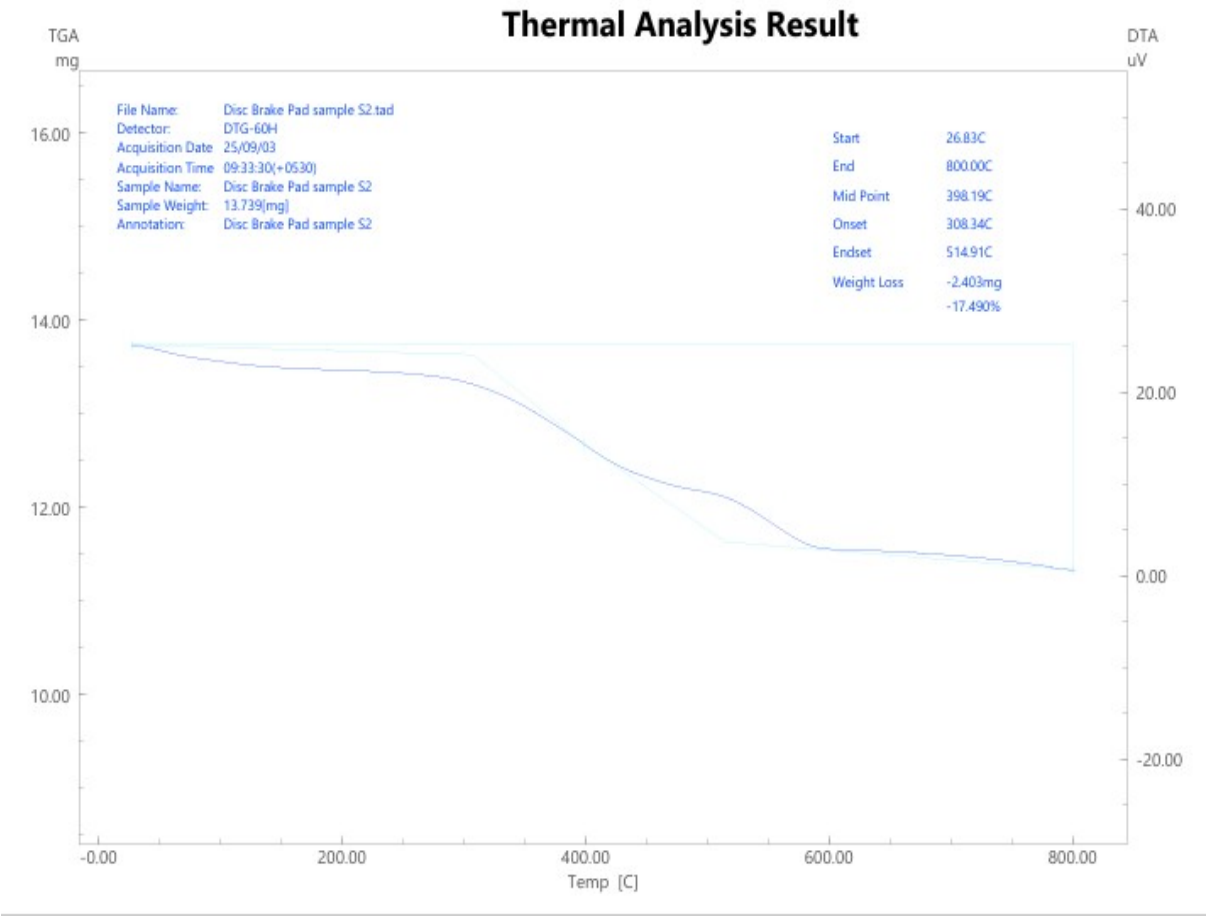
Table 13: Test Results as per ISO 6312 /SAE J840

Sr. No	Name of Test	Unit	Specification	Sample(S1)	Sample(S2)
11	Cold Shear Strength	Kg/cm2	25.50 Min	56.42	48.39
12	Adhesion	%	100	97	98

Table 14: Test Results as per JIS D 4418

Sr. No	Name of Test	Unit	Specification	Sample(S1)	Sample(S2)
13	Porosity	%	6 % target	6.41	6.18

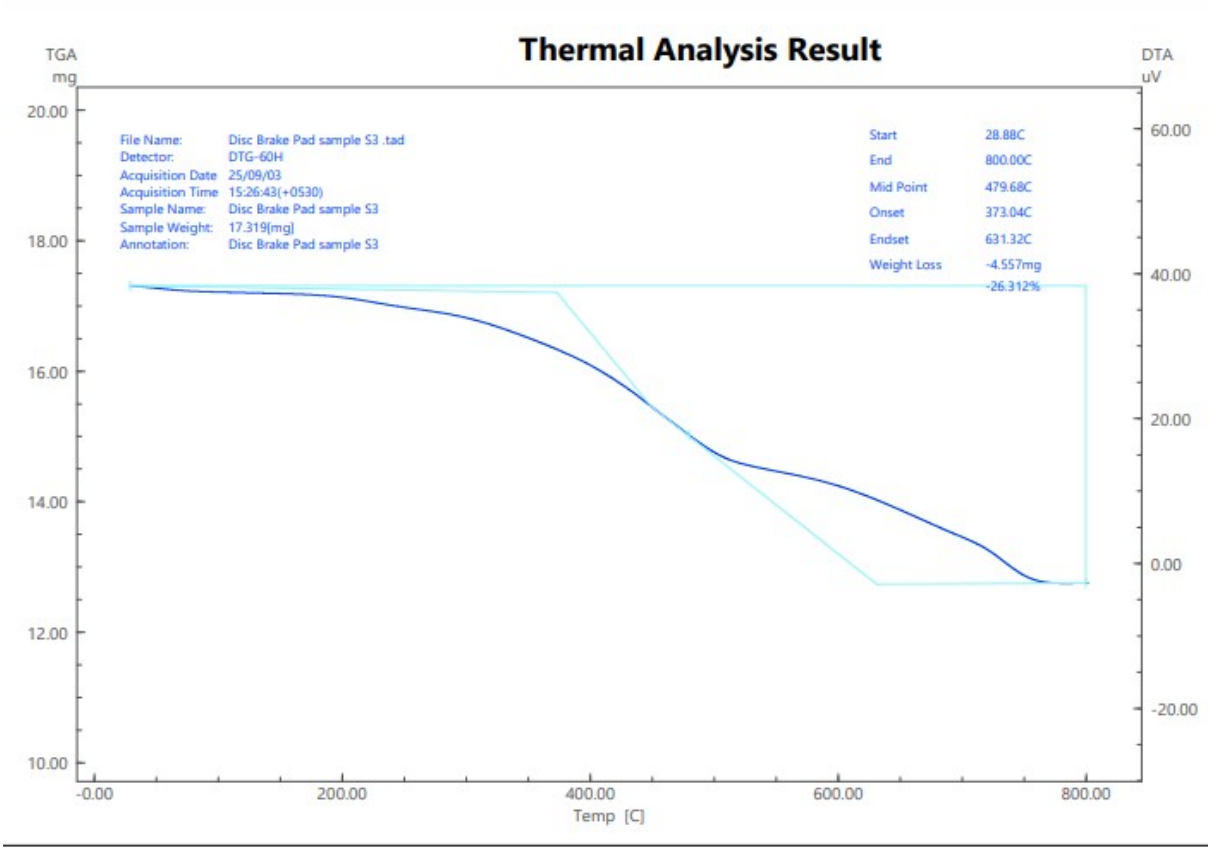
Thermo gravimetric analyzer — a scientific instrument used to measure changes in the weight (mass) of a material as a function of temperature or time under a controlled atmosphere.



Graph:Results of Thermo gravimetric analyzer for sampleS1

Above graph shows that it will stand with temperature up to 514^0C and weight loss up to 16%, it complete the test so it has negligible chances of failure during the actual field trails.

Graph:Results of Thermo gravimetric Analyzer for SampleS2



Graph:Results of Thermogravimetric Analyzer for SampleS2

Above graph Shows that it will withstand temperature up to 614^0C And weight loss up to 26%.

it complete the test so it chances of failure during the Actual field trail less.

Field Trail For Sample S1: The sample brake pads were fitted on a vehicle and tested under various environmental conditions for more than 16,000 km over a period of twelve months. During this observation period, the material underwent all required tests. The brake pads successfully performed without any functional failure, withstood the maximum operating temperature, and exhibited wear loss within the limits specified by SAE standards.

Wear Estimation Using Mathematical Models with Experimental Data for Sample S1.

The wear rate of brake material was studied and review by S.K.Rhee of Bendix Corporation the wear rate of a material was investigated in (1970,1971,1974) and the following general relationship was used to model the process(1970).

$\Delta W=\alpha P^a V^b t^c$

Where,

W=wear loss of brake material in grams.

P=normal pressure in psi.

V=sliding speed (rpm)

t=sliding time(min).

α=proportionality factor which depend upon testing geometry.

1 .1 $\Delta W=1*150*.44*7.92$

=522 grams.

Wear Estimation Using Mathematical Models with Experimental Data for Sample S2.

$\Delta W=\alpha P^a V^b t^c$

Where,

W=wear loss of brake material in grams.

P=normal pressure in psi.

V=sliding speed (rpm)

t=sliding time(min).

α=proportionality factor which depend upon testing geometry.

2.1 $\Delta W=1*150*.44*5.6$

=373 grams

Wear Estimation Using Mathematical Models with Experimental Data for Asbestos Material.

$\Delta W=\alpha P^{a}V^{b}t^{c}$

Where,

W=wear loss of brake material in grams.

P=normal pressure in psi.

V=sliding speed (rpm)

t=sliding time(min).

α=proportionality factor which depend upon testing geometry.

$\Delta W=1*150*.44*15$

=990 grams.

Conclusion

- Sample S1, developed and tested as per SAE J661, exhibits a normal coefficient of friction of 0.423, a hot coefficient of friction of 0.453, weight loss of 7.9%, and thickness loss of 8%.
- As per IS 2742:1999, Sample S1 shows a specific gravity of 2.48, hardness of 76.7,77.7 (both on and off the spigot hole), acetone extraction value of 0.58%**,** loss on ignition @850^0c (LOI) of 18.4, heat swell@200^0c of 0.08, and water swell @room temperature 0.09.
- According to ISO 6312 / SAE J840**,** Sample S1 demonstrates a cold shear strength of 56.42 MPa and adhesion strength of 97 MPa
- As per JIS D 4418**,** Sample S1 shows porosity of 6.1%.
- As per Wear Estimation Using Mathematical Models with Experimental Data for Sample S1 shows wear off 522 Grams
- As per Field trial data for more than 16000 km The brake pads successfully performed without any functional failure, withstood the maximum operating temperature, and exhibited wear loss within the limits specified by SAE standards.
- Sample S2, developed and tested as per SAE J661, exhibits a normal coefficient of friction of 0.390, a hot coefficient of friction of 0.443, weight loss of 8.0%, and thickness loss of 8.1%.
- As per IS 2742:1999, Sample S1 shows a specific gravity of 2.37, hardness of 80.2,66.3 (both on and off the spigot hole), acetone extraction value of 0.69%**,** loss on ignition @850^0c (LOI) of 19.4, heat swell@200^0c of 0.1, and water swell @room temperature 0.09.
- According to ISO 6312 / SAE J840**,** Sample S1 demonstrates a cold shear strength of 48.39 MPa and adhesion strength of 98 MPa
- As per JIS D 4418**,** Sample S1 shows porosity of 6.18%.
- As per Wear Estimation Using Mathematical Models with Experimental Data for Sample S1 shows wear off 573 Grams

Based on the above results, it is clear that both **Sample S1 and Sample S2** have the potential to replace conventional **asbestos-based brake pad materials**,.

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List of publications

1.Sandip Thengade & Dr.M.S.Kadam (2024,December 19-20)Analysis of Frictional & Wear Characteristics of Asbestos free Disc brake Pad Mechanical Engineering International Conference(MEICON-1.0)-Advancements, Innovation and Automation for Sustainability organised by J.P.Jindal university Raigarth ,C.H.India (Presented)

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3.Sandip L.Thengade & Dr.M.S.Kadam(2025). Performance Analysis Of Non Asbestos Disc Brake Pad .International Journal of Environmental Sciences, ISSN: 2229-7359 Vol 11No ,24S (Published Scopus indexed**).**

4**.**Sandip L.Thengade & Dr.M.S.Kadam(2025). Study and Analysis of Base line and Wear of Asbestos free PassengerCar Disc Brake Pad.GIS Science Journal Vol.12-issue8(Published Scopus indexed).

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